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Pressure-Induced (delta) to (alpha)' Phase Transformations in a Pu-Ga Alloy

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Well-homogenized Pu-2 at.% Ga alloys can be retained in the metastable face centered cubic δ phase at room temperature. Ultimately, this metastable δ phase will decompose via a eutectoid transformation to the thermodynamically stable monoclinic α phase and the intermetallic compound Pu_3Ga over a period of approximately 10,000 years. In addition, these low solute-containing δ-phase Pu alloys are also metastable with respect to low temperature excursions or increases in pressure. δ-phase alloys are known to undergo an incomplete isothermal martensitic phase transformation that results in a microstructure consisting of ~20 μm long lath-shaped particles of the α′ phase dispersed within the δ matrix. The ~20% volume contraction between the δ and α′ phases requires significant elastic and plastic accommodation. Transmission electron microscopy (TEM) has shown that the dislocation density in the vicinity of the tips of the α′ particles is about an order of magnitude larger than in the δ-phase matrix. The δ-phase will also transform to the monoclinic α′ phase at slightly elevated pressure. In this study, δ-phase Pu-Ga specimens, 2.3 mm diameter by 100 microns thick were compressed to approximately 1 GPa in a large volume moissanite anvil cell – shown in Figure 1 – to induce the transformation to α′.

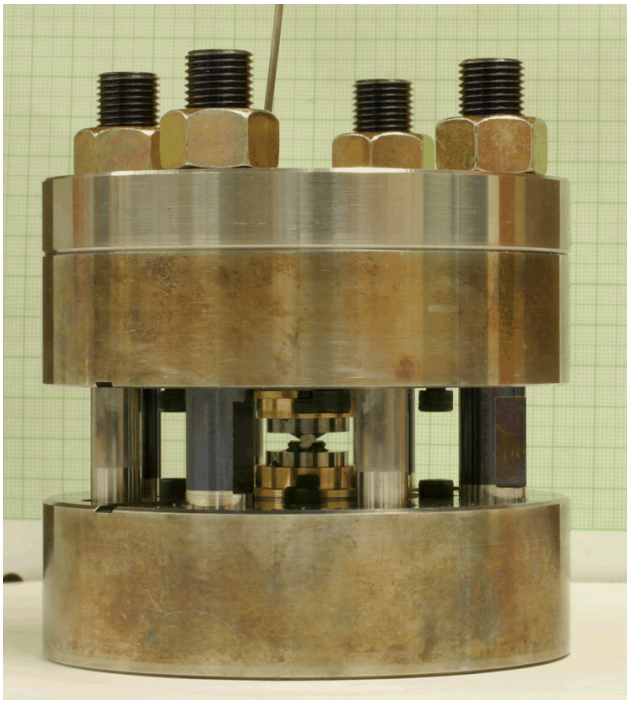

Fig. 1. Photograph of large volume moissanite anvil cell used for compressing TEM-sized samples.

The recovered samples were characterized at ambient pressure with optical microscopy, x-ray diffraction, and transmission electron microscopy. Optical microscopy revealed a very fine microstructure that appears to be single phase. This preliminary conclusion was supported by x-ray diffraction, which showed only the monoclinic reflections from the α' phase. However, TEM and electron diffraction revealed small regions of δ phase with a very high dislocation density interspersed between the 10 – 100 nm α' grains as shown in Figure 2.

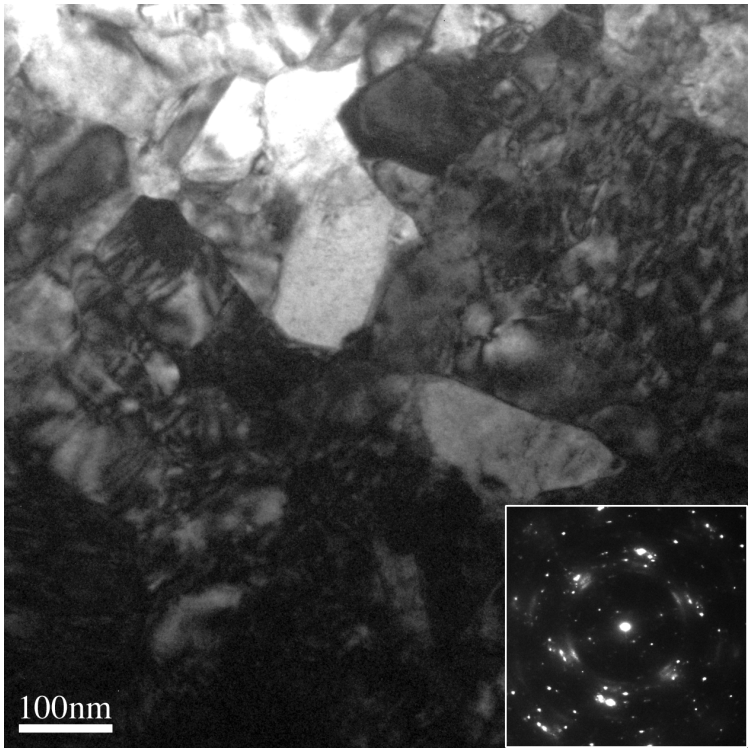

Fig. 2. Bright-field TEM image of a Pu – 2.0 at.% Ga sample that was compressed to 1 GPa and characterized at ambient pressure. The insert shows an electron diffraction pattern from a neighboring area that reveals Bragg peaks from both the $\langle 2$ and δ phases.

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